

In the Claims:

This listing of claims replaces all prior versions and listings of claims in the application.

1. (Currently Amended) A magnetic sensor comprising: a free magnetic layer in which a direction of magnetization is changed in accordance with an external magnetic field applied thereto; a fixed magnetic layer in which a direction of magnetization is fixed; a nonmagnetic material layer provided between the free magnetic layer and the fixed magnetic layer; and antiferromagnetic layers fixing the magnetization of the fixed magnetic layer by exchange coupling,

wherein lengths in a first direction of the free magnetic layer, the nonmagnetic material layer, and the fixed magnetic layer are formed larger than respective widths thereof in a second direction orthogonal to the first direction, the direction of magnetization of the free magnetic layer is preferentially oriented in the first direction by shape anisotropy,

the fixed magnetic layer has a multilayer structure composed of a second magnetic layer in contact with the nonmagnetic material layer, an interlayer, and a first magnetic layer provided in that order,

the antiferromagnetic layers are provided with an intermediate region having a predetermined length provided therebetween in the first direction so as to be in contact with the first magnetic layer,

a direction of magnetization of the first magnetic layer is fixed by the exchange coupling in a direction crossing the first direction,

a direction of magnetization of the second magnetic layer is fixed antiparallel to that of the first magnetic layer, and

electrical resistance is changed by the direction of magnetization of the free magnetic layer and that of the fixed magnetic layer at the intermediate region,

a nonmagnetic metal layer is disposed at the intermediate region, the nonmagnetic metal layer having the same composition as that of the antiferromagnetic layers, being in contact with the first magnetic layer, having a small thickness as compared to that of the antiferromagnetic layers to form an irregular crystal structure,

a crystal of the nonmagnetic metal layer and a crystal of the fixed magnetic layer at the intermediate region are placed in an epitaxial or a heteroepitaxial state, and the fixed magnetic layer has an open end surface at a face opposing a recording medium, and

the entire nonmagnetic metal layer or a part thereof in the vicinity of an interface with the first magnetic layer of the fixed magnetic layer has a face-centered cubic (fcc) structure, and equivalent crystal planes represented by a {111} plane are preferentially oriented in a direction parallel to the interface.

2-4. (Cancelled)

5. (Currently Amended) The magnetic sensor according to Claim 31, wherein the nonmagnetic metal layer has a thickness of 5 to 50 Å.

6. (Currently Amended) The magnetic sensor according to Claim 31, wherein the entire first magnetic layer of the fixed magnetic layer or a part thereof at least at the intermediate region in the vicinity of an interface with the nonmagnetic metal layer has a face-centered cubic (fcc) structure, and equivalent crystal planes represented by a {111} plane are preferentially oriented in a direction parallel to the interface.

7. (Original) The magnetic sensor according to Claim 6, wherein the first magnetic layer of the fixed magnetic layer comprises Co or Co_xFe_y in which $y \leq 20$ and $x+y=100$ are satisfied.

8. (Currently Amended) The magnetic sensor according to Claim 31, wherein the entire first magnetic layer of the fixed magnetic layer or a part thereof at least at the intermediate region in the vicinity of an interface with the nonmagnetic metal layer has a body-centered cubic (bcc) structure, and equivalent crystal planes represented by a {110} plane are preferentially oriented in a direction parallel to the interface.

9. (Original) The magnetic sensor according to Claim 8, wherein the first magnetic layer of the fixed magnetic layer comprises Co_xFe_y in which $y \geq 20$ and $x+y=100$ are satisfied.

10. (Currently Amended) The magnetic sensor according to Claim 31, wherein the first magnetic layer of the fixed magnetic layer at least at the intermediate region has a face-centered cubic (fcc) structure in the vicinity of an interface with the nonmagnetic metal layer, in which equivalent crystal planes represented by a {111} plane are preferentially oriented in a direction parallel to the interface, and has a body-centered cubic (bcc) structure in the vicinity of an interface with the interlayer, in which equivalent crystal planes represented by a {110} plane are preferentially oriented in a direction parallel to the interface with the interlayer.

11. (Original) The magnetic sensor according to Claim 10, wherein the first magnetic layer of the fixed magnetic layer has a composition represented by Co or Co_xFe_y (where $y \leq 20$ and $x+y=100$ are satisfied) in the vicinity of the interface with the nonmagnetic metal layer and has a composition represented by Co_xFe_y (where $y \geq 20$ and $x+y=100$ are satisfied) in the vicinity of the interface with the interlayer.

12. (Original) The magnetic sensor according to Claim 11, wherein the Fe concentration of the first magnetic layer of the fixed magnetic layer is gradually increased from the interface with the nonmagnetic metal layer to that with the interlayer.

13. (Currently Amended) The magnetic sensor according to Claim 31, wherein a value obtained when a difference between a nearest interatomic distance of the nonmagnetic metal layer in an in-plane direction parallel to the interface with the non-magnetic metal layer and that of the first magnetic layer of the fixed magnetic layer at least at the intermediate region is divided by a nearest interatomic distance of the first magnetic layer is in the range of from 0.05 to 0.20.

14. (Currently Amended) The magnetic sensor according to Claim 31, wherein the first magnetic layer comprises a magnetic material having a positive magnetostriction constant.

15. (Cancelled)

16. (Currently Amended) The magnetic sensor according to Claim 1, wherein vertical bias means is not provided for orienting a magnetization of the free magnetic layer in the first direction.

17. (New) A magnetic sensor comprising: a free magnetic layer in which a direction of magnetization is changed in accordance with an external magnetic field applied thereto; a fixed magnetic layer in which a direction of magnetization is fixed; a nonmagnetic material layer provided between the free magnetic layer and the fixed magnetic layer; and an antiferromagnetic layer fixing the magnetization of the fixed magnetic layer by exchange coupling,

wherein lengths in a first direction of the free magnetic layer, the nonmagnetic material layer, and the fixed magnetic layer are formed larger than respective widths thereof in a second direction orthogonal to the first direction, the direction of magnetization of the free magnetic layer is preferentially oriented in the first direction by shape anisotropy,

the fixed magnetic layer has a multilayer structure composed of a second magnetic layer in contact with the nonmagnetic material layer, an interlayer, and a first magnetic layer provided in that order,

the antiferromagnetic layer is provided with an intermediate region having a predetermined length provided therebetween in the first direction so as to be in contact with the first magnetic layer,

a direction of magnetization of the first magnetic layer is fixed by the exchange coupling in a direction crossing the first direction,

a direction of magnetization of the second magnetic layer is fixed antiparallel to that of the first magnetic layer,

electrical resistance is changed by the direction of magnetization of the free magnetic layer and that of the fixed magnetic layer at the intermediate region,

a nonmagnetic metal layer is disposed at the intermediate region, the nonmagnetic metal layer having the same composition as that of the antiferromagnetic layer, being in contact with the first magnetic layer, having a small thickness as compared to that of the antiferromagnetic layer to form an irregular crystal structure,

a crystal of the nonmagnetic metal layer and a crystal of the fixed magnetic layer at the intermediate region are placed in an epitaxial or a

heteroepitaxial state, and the fixed magnetic layer has an open end surface at a face opposing a recording medium, and

the first magnetic layer of the fixed magnetic layer at least at the intermediate region has a face-centered cubic (fcc) structure in the vicinity of an interface with the nonmagnetic metal layer, in which equivalent crystal planes represented by a {111} plane are preferentially oriented in a direction parallel to the interface, and has a body-centered cubic (bcc) structure in the vicinity of an interface with the interlayer, in which equivalent crystal planes represented by a {110} plane are preferentially oriented in a direction parallel to the interface with the interlayer.

18. (New) The magnetic sensor according to Claim 17, wherein the first magnetic layer of the fixed magnetic layer has a composition represented by Co or Co_xFe_y (where $y \leq 20$ and $x+y=100$ are satisfied) in the vicinity of the interface with the nonmagnetic metal layer and has a composition represented by Co_xFe_y (where $y \geq 20$ and $x+y=100$ are satisfied) in the vicinity of the interface with the interlayer.

19. (New) The magnetic sensor according to Claim 17, wherein the Fe concentration of the first magnetic layer of the fixed magnetic layer is gradually increased from the interface with the nonmagnetic metal layer to that with the interlayer.

20. (New) The magnetic sensor according to Claim 17, wherein a value obtained when a difference between a nearest interatomic distance of the nonmagnetic metal layer in an in-plane direction parallel to the interface with the non-magnetic metal layer and that of the first magnetic layer of the fixed magnetic layer at least at the intermediate region is divided by a nearest interatomic distance of the first magnetic layer is in the range of from 0.05 to 0.20.

21. (New) The magnetic sensor according to Claim 17, wherein the first magnetic layer comprises a magnetic material having a positive magnetostriction constant.

22. (New) The magnetic sensor according to Claim 17, wherein vertical bias means is not provided for orienting a magnetization of the free magnetic layer in the first direction.

23. (New) The magnetic sensor according to Claim 17, wherein the nonmagnetic metal layer has a thickness of 5 to 50 Å.

24. (New) A magnetic sensor comprising: a free magnetic layer in which a direction of magnetization is changed in accordance with an external magnetic field applied thereto; a fixed magnetic layer in which a direction of magnetization is fixed; a nonmagnetic material layer provided between the free magnetic layer and the fixed magnetic layer; and antiferromagnetic layers fixing the magnetization of the fixed magnetic layer by exchange coupling,

wherein lengths in a first direction of the free magnetic layer, the nonmagnetic material layer, and the fixed magnetic layer are formed larger than respective widths thereof in a second direction orthogonal to the first direction, the direction of magnetization of the free magnetic layer is preferentially oriented in the first direction by shape anisotropy,

the fixed magnetic layer has a multilayer structure composed of a second magnetic layer in contact with the nonmagnetic material layer, an interlayer, and a first magnetic layer provided in that order,

the antiferromagnetic layers are provided with an intermediate region having a predetermined length provided therebetween in the first direction so as to be in contact with the first magnetic layer,

a direction of magnetization of the first magnetic layer is fixed by the exchange coupling in a direction crossing the first direction,

a direction of magnetization of the second magnetic layer is fixed antiparallel to that of the first magnetic layer,

electrical resistance is changed by the direction of magnetization of the free magnetic layer and that of the fixed magnetic layer at the intermediate region,

a nonmagnetic metal layer is disposed at the intermediate region, the nonmagnetic metal layer having the same composition as that of the antiferromagnetic layers, being in contact with the first magnetic layer, having a small thickness as compared to that of the antiferromagnetic layers to form an irregular crystal structure,

a crystal of the nonmagnetic metal layer and a crystal of the fixed magnetic layer at the intermediate region are placed in an epitaxial or a

heteroepitaxial state, and the fixed magnetic layer has an open end surface at a face opposing a recording medium, and

a value obtained when a difference between a nearest interatomic distance of the nonmagnetic metal layer in an in-plane direction parallel to the interface with the non-magnetic metal layer and that of the first magnetic layer of the fixed magnetic layer at least at the intermediate region is divided by a nearest interatomic distance of the first magnetic layer is in the range of from 0.05 to 0.20.

25. (New) The magnetic sensor according to Claim 24, wherein the nonmagnetic metal layer has a thickness of 5 to 50 Å.

26. (New) The magnetic sensor according to Claim 24, wherein the entire first magnetic layer of the fixed magnetic layer or a part thereof at least at the intermediate region in the vicinity of an interface with the nonmagnetic metal layer has a face-centered cubic (fcc) structure, and equivalent crystal planes represented by a {111} plane are preferentially oriented in a direction parallel to the interface.

27. (New) The magnetic sensor according to Claim 26, wherein the first magnetic layer of the fixed magnetic layer comprises Co or Co_xFe_y in which $y \leq 20$ and $x+y=100$ are satisfied.

28. (New) The magnetic sensor according to Claim 24, wherein the entire first magnetic layer of the fixed magnetic layer or a part thereof at least at the intermediate region in the vicinity of an interface with the nonmagnetic metal layer has a body-centered cubic (bcc) structure, and equivalent crystal planes represented by a {110} plane are preferentially oriented in a direction parallel to the interface.

29. (New) The magnetic sensor according to Claim 28, wherein the first magnetic layer of the fixed magnetic layer comprises Co_xFe_y in which $y \geq 20$ and $x+y=100$ are satisfied.

30. (New) The magnetic sensor according to Claim 24, wherein the first magnetic layer comprises a magnetic material having a positive magnetostriction constant.

31. (New) The magnetic sensor according to Claim 24, wherein vertical bias means is not provided for orienting a magnetization of the free magnetic layer in the first direction.